OBSERVATIONS UPON LONG-DISTANCE RUNNERS.

EDITED BY

J. B. BLAKE, M.D.,

AND

R. C. LARRABEE, M.D.

Reprinted from the Boston Medical and Surgical Journal

Vol. cxlviii, No. 8, pp. 195–206, February 19, 1903.

BOSTON

THE OLD CORNER BOOK STORE (INCORPORATED)

283 WASHINGTON STREET

1903

OBSERVATIONS UPON LONG-DISTANCE RUNNERS.

EDITED BY J. B. BLAKE, M.D., AND R. C. LARRABEE, M.D.

THE final and culminating event in the Greek Olympian Games of 1896 was a foot race from the battlefield of Marathon to the stadium in Athens. The distance is 40 km., and the race was open to contestants from all parts of the world. The contest was won by a Greek shepherd, none of the French, German, English or American runners being in sight at the finish.

Several members of the Boston Athletic Associaciation competed in those games. Since that time the association has held an annual Marathon run on Patriots' Day, over a course of equal length, from Ashland to the clubhouse on Exeter Street. In 1899 Drs. Williams and Arnold[1] reported the results of observations upon the contestants of that year; and the results of a series of similar observations during the past three years are here presented.

The examinations were made before the start and immediately after the finish of the contests. As some of the physical signs are modified or even entirely disappear very quickly after the race, it was necessary to have a large number of observers trained and assigned to particular duties. This resulted in a very large mass of data which it seemed best to condense and edit in the present form. The facts obtained, and the conclusions drawn, are given first. Methods and results of examinations and individual observations are added in greater detail for the benefit of future observers, or those specially interested in the subject.

The length of the course is twenty-four miles. The road is an average New England highway for two thirds of the distance, and for the remainder is the hard macadam surface characteristic of Boston's parkways. The course covers a rolling country, one or two hills, notably in Newton, being extremely long and trying. The general trend of the slope is downward.

No restrictions are put upon the runners, save that they shall proceed on foot over the specified route and shall not receive any assistance. They may, therefore, eat or drink what they please during the race. Each contestant is accompanied by an official guard on a bicycle, usually a volunteer from the Ambulance Service of the State Militia.

The costume of the runners is extremely light, consisting of cotton shirt and running pants and fairly heavy leather shoes or "sneakers," laced about the ankles and generally worn without stockings. The contestants were of various nationalities, including one Greek and one Mohawk Indian. Their ages ranged from sixteen years upwards; their occupations from laborers to students; their athletic standing was described by that somewhat elastic and much-discussed term "amateur." At the end of the race they were taken in the elevator to the dressing rooms of the clubhouse and immediately examined. After this they took a warm bath, were given a rubdown and a light lunch, and shortly started for home, usually without assistance.

Pulse. — The rate was always increased in frequency, though the increase was often surprisingly small. It was least in the best-trained men and in those who finished slowly. In some instances it was almost as slow at the finish as at the start — notably in the winner of 1902. A very rapid pulse (over 150) was unusual.

A moderate irregularity was not infrequent.

An intermittent pulse was occasionally present.

A threadlike pulse of small volume was found in the rare cases of severe fatigue.

On the whole, the radial pulse was a fair index of the condition of the runner, though the rate alone often proved misleading.

Weight. — The estimation of the loss of weight was only approximate, for reasons given later. It varied from two to seven pounds, the extremes being one and ten pounds.

The amount lost was apparently determined by a combination of factors, including the original body weight and physical condition, the speed, the amount of solids and liquids consumed during the race and the atmospheric conditions.

Temperature. — Before the start, the mouth temperature showed not infrequent variation from the normal. This was usually a fraction of a degree, but in some instances reached 100.6°.

After the finish the mouth temperature was sometimes raised, often normal and occasionally subnormal. The rectal temperature, however, was invariably raised. In the entire three years only three exceptions were found to this rule, which will be discussed and explained below.

The difference between mouth and rectal temperature, taken simultaneously, was often surprisingly large, reaching in one instance 7°. The explanation of this interesting fact is that the men ran with open lips, and the forced and continuous breathing of cold air lowered the temperature of the mouth cavity.

The surface of the body was almost invariably cool and sometimes cold, but no distinct chills were observed.

Sphygmographic pulse tracings. — (1) Violent and prolonged muscular exercise invariably causes an alteration in the character of the pulse curve, as shown by the sphygmograph.

(2) This change in the character of the tracing is dicrotic in nature and due to a lowering of arterial tension.

Blood. — The principal finding has a leucocytosis corresponding in intensity and in type with that observed in various inflammatory diseases.

Hearts. — Before the start, the hearts invariably showed enlargement, due mainly or wholly to hypertrophy. At the finish, in practically all cases, there was further slight enlargement, inferred to be the result of acute dilatation.

In some cases murmurs, generally systolic, were heard; some were heard at the start, and were considered to be the result of nervous excitement. Concerning the nature of a number heard at the finish there is considerable doubt; we no not feel justified in asserting that they were due to mitral regurgitation.

Urines — The examination of the urine shows

[1] "The Effects of Violent and Prolonged Muscular Exercise upon the Heart." Phil. Med. Journ., June 3, 1899.

that in every case an active hyperemia is developed during the race, probably due largely to the irritation from the "toxins of fatigue," inasmuch as the blood pressure is not increased. This condition clears up quickly, as albumin and casts had disappeared in all the cases examined one week after the race.

The *amount* of urine for twenty-four hours is lessened, the *color* becomes higher, the *specific gravity* rises and the *reaction* becomes more intensely acid. *Albumin* appears in quantities varying from the slightest possible trace to a trace, and in the *sediment* we find in every instance hyaline and fine granular casts, a few coarse granular and epithelial casts and more or less blood, normal and abnormal, free and on casts. Rare brown granular casts are found in some sediments, and calcic oxalate crystals in the majority.

The *urea* is not increased after the race, but, on the contrary, appears in the majority of cases to be less for the first twenty-four hours following the race than for the last twenty-four hours before the race. By the end of a week, however, it has again risen to normal.

PULSE RATES AT FINISH.

	[1]1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1900 . .	108	120	120	144	108	116	96	88	72	107	100	98	106	88	132	104	128	80	96	104
1902 . .	82	108	126	132	132	96	144	144	160	120	162	136	180	140	160	164	156	146		

The pulses of the first two men in 1902 were very slow, but, even with these exceptions, the pulses of 1902 were faster than 1900.

The following table compares the pulse rates before and after the race of 1900:

BEFORE AND AFTER RACE, 1900.

1900	[1]1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Before	100	80	72	76	84	84	72	104	84	72	80	82	80	80	92	120?	126
After	108	120	120	144	116	88	100	98	106	88	132	104	80	96	104	134	116

In this table there are three cases where the pulse at the start was as fast or even faster than at the finish. These men finished slowly, and a few minutes elapsed before the pulse was taken. At the start the men differed much in composure, many even of the veterans being extremely nervous; whereas at the finish, with few exceptions all were stolid with fatigue.

The *chlorides* are markedly diminished after the race. It is probable that the output of *uric acid* is diminished, and that of *phosphorus* increased, but the results vary so much that no definite conclusions can be drawn.

PULSE, WEIGHT AND TEMPERATURE.

BY J. B. BLAKE, M.D., AND D. D. SCANNELL, M.D.

Pulse. — The pulse rate seemed to depend on three factors: First, the condition of the heart itself; second, the character of the exertion, particularly in the last few minutes of the race; third, the time which elapsed between the actual finish and the observation of the pulse. The hearts best prepared for the contest seemed to have the slowest rates. These hearts were always hypertrophied, but were not overworked by excessive training. In each of the three contests, however, occasional slow pulse rates were observed in which the hearts were not in particularly good condition. These we believe to be the exception and not the rule. The second factor influencing the rate was very effective — a man may have covered the entire distance to within half a mile of the end at a slow rate of speed, and may then have run very fast either racing a neighbor or encouraged to make a creditable appearance before the thousands lining the sidewalks — his final exertion would send the pulse rate up enormously; whereas the reverse also occurred, and a contestant who had run fast for most of the course might slow down at the finish, particularly if he was far ahead of the next runner; his pulse rate would already have diminished materially before the end of the race. The third factor, the time elapsing before the observation, was also important. Two or three minutes are sufficient to change a very rapid to a moderately rapid pulse. This is shown in the following table, which compares the pulse rates after the 1900 race with the race in 1902. It will be seen at a glance that the 1902 average is faster, yet the time of the race and the condition of the men were about equal. The only varying factor was the time which elapsed before counting the pulse. In 1900 two or three minutes elapsed before the runner was stretched upon the table in the examining room; in 1902 the observer was in the elevator, and took the pulses as the men stepped from the street.

Weight. — These observations were less accurate than those of pulse or temperature, because they were open to the following sources of error: First, difference in scales; second, solids and liquids ingested during the race; third, small articles of clothing. As it is difficult to accurately calculate the first of these, and entirely impossible to estimate the second, it is obvious that the following figures can be accepted as only moderately accurate.

The extremes of one-half pound (one case) and one pound (one case) on the one hand and ten pounds (one case) on the other may be disregarded. Without doubt the first two were much influenced by the above-mentioned source of error. A large majority of the cases would be found to lie within the three- to six-pound limit. This was certainly a moderate loss, and though the time was three times that of a football game, and ten times that of the average four-mile boat race, not only the average but even the maximum loss was less than has been noted in either football or rowing. In general the heaviest men and those who ran fastest lost the greatest amounts, though there were many exceptions to this.

[1] These figures represent the position of the men at the finish.

The heaviest man of whom we have any record during the three years weighed only 166½. He did not finish. The heaviest who completed a race was 155. The lightest starter weighed less than 100. The lightest who finished weighed 104. Obviously, these are not contests for heavy weights.

Tables of Weights.

1900	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Before	125¾	121	130	137½	126	141	124	155	104	124½	123¼	131	134½	115¼
After	120¼	114	124	130¾	120	134½	120½	147¼	100¼	119¾	117½	121	133	111¾

1901	1	2	3	4	5	6	7	8	9	10	11	12	13
Before	147¾	131	110⅛	152⅛	134½	111	127	139½	110⅛	120¼	122	139⅛	130½
After	143¾	126¾	108	147½	129¼	107½	124½	133	107⅛	116	120	132¼	130

1902	1	2	3	4	5
Before	135	130½	114	132	142½
After	127½	124¾	109½	126½	137½

Temperature. — These observations were considerably more accurate than those of the weight, and were taken by mouth before the start and by mouth and rectum simultaneously immediately after the finish. The clinical thermometers used were similar to those found in the large Boston hospitals, and were presumably correct to $\frac{2}{10}$ of a degree.

1900		1	2	3	4	5	6	7	8	9	10	11	12
Before — Mouth		98.6°	99.2°	98.0°	100.4°	99.5°	98.6°	99 0°	100.6°	100 4°	98.8°	98.2°	100.4°
After	Mouth	98.3°	99.6°	102.2°	97.4°	99.7°	98.6°	97.0°	97.4°	101.5°	97.2°	99.8°	97.6°
	Rectum	104.4°	99.4°	101.4°	103.8°	104.0°	98.0°	104.0°	101.0°	103.4°	100.0°	103.0°	102.6°

1900 (*continued*)		13	14	15	16	17	18	19	20	21	22	23	24
Before — Mouth		100.7°	100.2°	100.0°	99.8°	100.5°	98.2°	. .	. .	. .	. .	. .	. .
After	Mouth	100.2°	100.8°	100.8°	99.6°	99.6°	97.8°	100.2°	98.4°	97.4°	100.4°	98.4°	99.6°
	Rectum	101.3°	103.0°	102.3°	103.3°	102.6°	102.8°	103.3°	103.8°	99.0°	104.3°	103.3°	103.3°

1901		1	2	3	4	5	6	7	8	9	10
Before — Mouth		99.4°	98.0°	97.2°	98.3°	98.9°	98.9°	98.3°	98.7°	97.1°	98.0°
After	Mouth	. .	98.0°	98.2°	. .	97.5°	97.4°	. .	97.8°	98.0°	99.2°
	Rectum	102.3°	102.4°	104.4°	101.2°	101.4°	100.9°	100.0°	101.3°	96.0°	100.6°

1902		1	2	3	4	5	6	7	8	9	10	11
Before — Mouth		. .	. .	. .	98.6°	99.1°	98.6°	. .	. .	. .	. .	. .
After	Mouth	97.6°	100.6°	99 9°	97.4°	99.4°	97.9°	99.0°	98.8°	97.0°	98.1°	98.8°
	Rectum	101.7°	102.7°	103.0°	102.0°?	100.7°	100.4°	102.0°	101.0°	102.6°	103.5°	102.0°

These tables show that much more attention was paid to the temperatures in 1900 than in 1901 or 1902. The results are essentially the same, however; the 1900 shows a proportionately higher average both before and after the race. No less than eight out of eighteen examined before the race in this year had a temperature varying from 100° to 100.7°. There is no obvious explanation of this fact. All these men were in good condition and strong enough to finish. They did not have unusually high temperatures at the finish, nor did they show unusual fatigue. In fact, during the entire three years no definite relation could be established either between the temperatures before and after the race, or the relation of high or low temperature to loss of weight or extreme fatigue.

The important fact demonstrated by the observations of these three years on 45 men is that the mouth temperature is not a reliable factor. The reason is plain. The temperature of the air was colder in 1900 than in the other years; and in 1899, when extreme subnormal mouth temperatures were noted by Williams and Arnold, the air was colder than even in 1900. Every one knows that forced mouth breathing accompanies all severe muscular exercise, unless it be of the briefest duration. Under the conditions of these races there is no reason why the mouth should not become almost as cool as the surface of the body. For the time being it is no longer a closed cavity. On the other hand, the rectal temperature has invariably raised, the three exceptions being, first, a man who by mistake or intent was dosed with considerable quantities of alcohol; — this man was a teetotaler and supposed he was being given hot beef tea; he was plainly tipsy at the finish; — second, a man who also had a large amount of alcohol and who was so restless that it is questionable if the thermometer really entered the sphincter; third, a

man exhausted more than the average, also overstimulated, the only one of the three whose condition was not as good as the average at the finish. Other contestants may and probably did drink certain amounts of brandy while running, but none showed the effects of it, and no evidence was obtained that a subnormal temperature depends either on overtraining or extreme fatigue.

Forced exertion of this character raises the body temperature. Other agents, acting simultaneously, may cool exposed portions of the body. In rare instances the ingestion of large doses of alcohol seems to prevent the body temperature itself from rising.

REPORT ON PULSE TRACINGS TAKEN FROM THE MARATHON RUNNERS IN THE RACES OF 1900, 1901, 1902.

BY ALLEN CLEGHORN, M.D.

YEAR.	Complete record. (Start and finish.)	Start only.	Finish only.
1900	11	4	9
1901	2	5	4
1902	4	3	5
Totals . . .	17	12	18

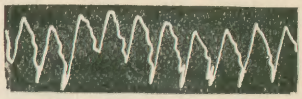
THE above table refers to the number of tracings obtained in the different years. From two runners only were complete tracings obtained in these three years, while from five, tracings were taken in two consecutive years, — naturally these tracings are the most valuable. Then follow the *complete* individual records obtained in the different years, and lastly in importance come the "*Start only*" and "*Finish only*" tracings. However, it is possible by combination to make a general comparison between these latter, and they show just as great a difference in the character of the curve as do the "complete records."

The method employed to obtain the pulse curves was the same that is used in the physiological department of Harvard Medical School. It consisted in placing a glass thistle tube over the right carotid artery at a level with the lower border of the thyroid cartilage. The thistle tube was connected with a very delicate tambour writing on the smoked surface of a revolving drum. The thistle tube was held on the neck of the contestant by the observer, the pressure over the artery being varied until the lever was found to give the greatest incursion when the tracing was recorded. In all cases the subject was seated during the observation. This method was adopted because it could be manipulated with greater ease and speed than either Dudgeon's or Marey's sphygmograph.

The results were uniform; the candidate invariably presented at the start of the race a normal pulse curve, but at the finish the curve was found to be profoundly altered, the tracing pointing to a condition of enormously low arterial tension. In some cases the pulse was extremely dicrotic. In about two thirds of the cases it was also found that the pulse was markedly irregular, but in the year 1900 no irregularity was noticed in the runners who finished first, second and third.

TYPICAL PULSE TRACINGS.

BEFORE.



AFTER.

Discussion of Results. — These observations open up some interesting points for consideration. All competitors lost considerable weight during the race, presumably by loss of water through sweating, etc. Is the low arterial tension the result of a concentration or lessening of the quantity of the blood circulating in the vessels, and consequently the vessels not being completely filled? Is it due to the action of the "depressor nerve" endeavoring to ease the overworking heart by increasing the caliber of the arterioles, and so lessening peripheral resistance, or is it due to an active dilatation of the arteries caused by the circulation in them of fatigue products, CO_2, etc.? My individual observations do not definitely point to any one of these problematical causes more than another, but, combined with the results of the other observers, would suggest that all these factors are probably concerned in producing this low tension pulse.

BLOOD PRESSURE.

Twice, during the three years occupied by this series of investigations, were attempts made to measure the blood pressure of the various contestants, both at the beginning and at the finish of the race. These experiments were made in the years 1900 and 1902.

In the former year a modified form of Mosso's apparatus was used. It was found troublesome to transport and to work; it consumed too much time in adjusting, and in obtaining the graphic record, etc., serious defects when celerity was required at the finish. In the latter year another form of tonometer was employed. This instrument is considerably less in bulk, fitting an ordinary pocket, and is much simpler to apply than the former, but on investigation it was found to be measuring the peripheral (capillary) circulation and not the arterial pressure. Consequently both methods, although the best we could devise, were unsatisfactory.

In the results obtained by these two methods the individual variation in pressure was so great that it was deemed best to reject them, only one point being as a rule maintained throughout; that is, in the majority of cases the blood pressure, as measured by Mosso's apparatus, and the peripheral pressure, as measured by the tonometer, were, in the various contestants tested, usually lower at the finish of the race than at the start.

Through an unfortunate error these two pulse tracings have been inverted and wrongly labeled. "Before" should read "after" and "after" should read "before."

THE BLOOD.

BY RALPH C. LARRABEE, M.D., WILDER TILESTON, M.D., AND WM. R. P. EMERSON, M.D.

THE following results were obtained from a study of the blood in certain of the contestants in the races of April 19, 1901, and April 19, 1902. The total number of cases observed was eleven, in two of which the observations were so incomplete as to be of little value. The red and white counts were made with the Thoma apparatus. An effort was made in 1902 to estimate the hemoglobin before and after the race with the Tallqvist scale, but the results were found to be so variable that they were discarded. This method, admirable as it is for the approximate estimation of the hemoglobin in clinical work, is far too inaccurate to be of service in an investigation of this sort.

In making the differential counts the specimens were stained in 1901 by the Ehrlich triple stain, and no effort was made to count the mast cells. In 1902 two methods of staining were used — Wright's modification of the Leishman method and the Ehrlich triple stain, with the additional brief dip in methylene blue as advised by Hewes to show the mast cells. Except in some of the normal specimens obtained before the race in 1901, a thousand cells were counted in each instance.

The method of procedure was as follows: The blood was first collected at Ashland during the hour before the start. In 1901 the diluted blood in the pipettes was taken to Boston and counted after an hour or two. In 1902 the examiners remained in Ashland till a later train, and made the white counts as soon as the material was collected. Probably no specimen waited over a half hour. At each puncture six spreads were made and dried in the air on cover slips. At the finish the blood was collected in the same way and examined at once. Two of the preliminary white counts and all the preliminary red counts were made a few days before the race. In two men who gave up after running fourteen or fifteen miles the blood was not obtained till they reached Boston by train, one and a half and three hours respectively after they had ceased to run. These exceptions are noted in the table.

The classification of leucocytes adopted needs little comment. Under "large mononuclears" we have included the "transitional forms" of Ehrlich, those which have indented, horse-shoe shaped or beaded nuclei but no protoplasmic granules. As myelocytes we have classed all mononuclear neutrophiles. The intermediate forms between these and true polymorphonuclear neutrophiles, that is, neutrophiles having indented or horse-shoe shaped nuclei, have been counted as polymorphonuclear neutrophiles.

The blood before the race showed no very striking abnormalities. In the case of J. L. in 1902

NAME.	Year.	BEFORE RACE.								AFTER RACE.								REMARKS.
		*Reds.	Total Whites.	Polymorphonuclear Neutrophiles.	Small Mononuclears.	Large Mononuclears and Transitionals.	Eosinophiles.	Mast Cells.	Myelocytes.	Reds.	Total Whites.	Polymorphonuclear Neutrophiles.	Small Mononuclears.	Large Mononuclears and Transitionals.	Eosinophiles.	Mast Cells.	Myelocytes.	
J. L. . .	1901	. . .	*5,800	63.2% 3,666	26.8% 1,554	8.2% 476	1.8% 104	. .	0	. . .	16,200	90.3% 14,629	4.5% 729	4.4% 713	0	. .	0.8% 130	Many cells intermediate between polymorphonuclears and myelocytes.
H—ks . .	„	. . .	4,800	72.8% 3,494	18.2% 874	8.2% 394	0.8% 38	. .	0	. . .	14,400	88.5% 12,744	7.0% 1,008	4.4% 634	0	. .	0.1% 14	
McA. . .	„	. . .	3,700	72.0% 2,664	14.6% 540	10.6% 392	2.6% 96	. .	0.2% 7	. . .	20,800	83.8% 17,430	7.8% 1,622	8.2% 1,706	0.2% 42	. .	0	
P.	„	. . .	*8,200	74.0% 6,068	18.4% 1,509	5.6% 459	2.0% 164	. .	0	. . .	22,200	86.1% 19,114	6.6% 1,465	7.1% 1,576	0	. .	0.2% 44	Few cells intermediate between polymorphonuclears and myelocytes.
J. L. . . .	1902	4,450,400	4,333	57 5% 2,491	29.4% 1,274	12.2% 529	0.8% 35	0.1% 4	0	4,340,800	14,200	86.4% 12,269	6.5% 923	6.8% 965	0	0	0.3% 43	Pale, much exhausted.
C.	„	(Apr. 17) 4,808,000	5,200	66.6% 3,464	19.7% 1,024	11.4% 593	1.7% 88	0.6% 31	0	6,074,400	20,400	88.5% 18,055	2.2% 449	9.1% 1,856	0.1% 20	0.1% 20	0	Good condition at finish.
H—n . .	„	(Apr. 17) 4,872,000	5,700	70.1% 3,996	18.5% 1,055	9.9% 564	1.2% 68	0.3% 17	0	Not taken	18,200	83.7% 15,234	6.9% 1,256	9.0% 1,638	0.2% 36	0.1% 18	0.1% 18	Ran but 14 miles. Examined 3 hours after finish.
P.	„	(Apr. 17) 5,392,000	8,000	53.9% 4,312	28.2% 2,256	13.4% 1,072	3.7% 296	0.8% 64	0	5,418,600	27,500	79.6% 21,890	6.7% 1,843	13.1% 3,603	0.3% 82	0.1% 27	0.2% 55	
H—ks . .	„	5,516,000	6,000	71.7% 4,302	19.6% 1,176	7.6% 456	0.8% 48	0.3% 18	0	6,168,000	22,600	87.4% 19,752	4.2% 949	8.2% 1,853	0.1% 23	0	0.1% 23	Cyanosis. Ran but 15 miles Examined 1½ hours after finish.
F.	„	4,826,000	7,600	. .	. .	. .	. .	. .	. .	. . .	22,600	. .	. .	. .	. .	. .	. .	Ran but 12 miles. Examined 2 hours after finish.
Z.	„	. . .	. .	. .	. .	. .	. .	. .	. .	. . .	27,700	. .	. .	. .	. .	. .	. .	16 years old.

* Preliminary red counts made two days before the race.

there was an abnormally low red count. This man was pale and did not appear to be in the best of condition. He finished third, in rather poor shape. No further cause for the anemia was found. Two men showed percentages of polymorphonuclear neutrophiles somewhat below normal. One of these was the man J. L. just mentioned as being in poor condition. The other, P., appeared to be in excellent condition, though he was eleven pounds heavier than in 1901. The other men, for the most part, showed rather high counts of polymorphonuclear neutrophiles, which is perhaps to be expected in young men in the best physical condition.

At the finish marked changes were found in the red, white and differential counts. It will be convenient to speak of these in order.

Red counts were secured in but four cases both at start and at finish, and one of these did not complete the race. Two showed no marked change, but the other two showed decided increase. One of the latter, C., finished sixth in excellent condition, his time being three hours and seven minutes. The other, H—ks, stopped running after fifteen miles, came in by train, and was examined one and a half hours after he ceased to run. He was slightly cyanotic. The explanation of this increase in reds is probably to be found in concentration due to loss of fluid.

White counts were obtained in every case before and after the race. They showed without exception a leucocytosis which varied from 14,200 to 27,700, and which was present in those who did not finish as well as those who did. The highest figure was obtained in the case of Z., a boy of sixteen, who finished the race in good form, jumped up on the examining table without help, and calmly announced that he had falsely stated his age as nineteen in order not to be excluded.

The differential counts showed that the greatest increase was in the polymorphonuclear neutrophiles, which were in every case much more numerous, both relatively and absolutely, at the finish than at the start. In the mononuclear elements the changes were equally striking and constant. The percentage of large forms as compared with the small ones was invariably increased. In all but two cases, in fact, the large forms exceeded the small ones at the finish, while at the start the small ones were invariably the more numerous. As regards absolute numbers per cubic centimeter there was always an increase in the large mononuclears during the race, while in the small mononuclears there was an absolute decrease in five out of the nine cases studied. Eosinophiles were in all cases both relatively and absolutely decreased. In four cases they were absent at the finish. The mast cells showed similar changes. In seven of the nine cases a few myelocytes were found. They were perhaps more numerous than the figures indicate, as we counted as polymorphonuclear neutrophiles a certain number of cells having neutrophilic granules but more or less indented nuclei. In fact, in 1901, two cases showed numerous cells intermediate between polymorphonuclear neutrophiles and myelocytes concerning whose classification there was much doubt. No abnormalities were noticed in the size, shape or coloring of the reds and no nucleated red cells were seen.

In commenting upon these changes in the leucocytes it must be remembered that an increase in the white corpuscles may be due to an increase in all the forms alike, so that the percentages of the different varieties remain the same, — the so-called "physiological type," such as is seen during digestion, in pregnancy and after parturition, massage or cold baths. Or it may be due to an increase in one or more of the individual varieties of leucocytes. The commonest and most significant is the "inflammatory" type of leucocytosis, seen in many inflammatory and toxic conditions, where the increase is wholly or mainly in the polymorphonuclear neutrophiles.

Schultz has shown that brisk exercise of brief duration causes a moderate leucocytosis of the physiological type. The highest count obtained by him was 13,600. The leucocytosis was transitory, entirely disappearing after fifteen minutes. Schultz explained the increase in white cells on the supposition that the increased activity of the circulation carried to the periphery leucocytes which had been at rest in the great internal veins.

Our cases in no way agree with this description. In degree the white counts obtained far exceed Schultz' figures. In kind they show that the increase was made up of two varieties of cells, namely, the polymorphonuclear neutrophiles and the large mononuclears, the changes in other forms being relatively inconsiderable in their effect on the total white count. Of the two the increase in polymorphonuclear neutrophiles was proportionately much the greater. In other words, our cases showed a leucocytosis of the inflammatory type rather than of the physiological.

This disagreement is probably to be explained by the fact that the usual view is based on the study of comparatively brief and slight degrees of exertion — such as short runs or brief exercise with apparatus in the laboratory. Even though such exercise may produce extreme dyspnea and acute fatigue, it is quite a different thing from a twenty-five-mile race under conditions of the most strenuous competition. When it is stated that the leader in the race of 1901 covered the twenty-five miles in a trifle less than two and a half hours it will be evident that this is a study of extreme exhaustion rather than "exercise."

A closer correspondence exists between our results and those of F. G. Burrows in a study of the leucocytosis associated with convulsions. As in our cases, he found considerable increase in the total leucocytes, with preponderance of the polymorphonuclear forms, increase of the large mononuclears, decrease of eosinophiles, and the appearance of a few myelocytes; though in his larger series a few exceptions to some of these particulars were noted. He found evidence that the leucocytosis was the result of a double cause — first, a moderate increase of the physiological type (all forms alike), and second, added to the first, a leucocytosis of the inflammatory or toxic type. The former he found to be temporary, the latter more persistent. Where both causes acted together a higher total count would result than from the toxic cause alone, but the percentage of polymorphonuclear neutrophiles would be less than later when the physiological element had subsided, leav-

ing only the pure inflammatory form. From the study of a case of general paralysis with violent frenzy but no convulsions and of a healthy student after a short, violent run, he infers that muscular work alone is not capable of producing a leucocytosis of the inflammatory type. Our figures prove that this inference was erroneous.

The question then arises, May not the leucocytosis in our cases be due to a double cause: muscular work acting mechanically to produce physiological leucocytosis plus a toxemia from fatigue products acting chemically to produce toxic leucocytosis? It has been amply proven that brief exercise produces an increase in all the forms of white cells alike, and we may assume that the cases here studied had such an increase during the early part of the race. Yet at the finish their leucocytoses were always characterized by a disproportionate increase in the polymorphonuclear neutrophiles. Inspection of our tables throws but little light on this interesting view, and the conclusions reached by one of us as a result of the first year's work were not fully verified by the added experience of a second year.

The significance of the remarkably constant change in the relative numbers of small and large mononuclears we are unable to explain. The decrease in eosinophiles is seen in leucocytosis from many diseases. Its importance here is that it brings our cases more nearly into line with the conditions found in pathological states. Mechanical changes pure and simple might conceivably increase one form of cell more than another, but would hardly cause the entire disappearance or very marked decrease in one form alone. The same thing may be said of the decrease in mast cells.

The occurrence of a few myelocytes has also been noted in marked leucocytosis from various causes. Their occurrence, together with the forms intermediate between myelocytes and polymorphonuclear neutrophiles, is of interest in connection with the view that the myelocytes give rise to the polymorphonuclear neutrophiles by changes in the shape of the nucleus. It is probable that the increased activity of the circulation sweeps from the marrow these "unfinished" forms.

If further work of this sort is to be done we would suggest the advisability of successive examinations at short intervals after the race till the blood becomes normal, a suggestion which is emphasized by the fact that two men who ran but fourteen or fifteen miles and were examined several hours later still showed the blood changes in full severity. If possible one or more observations during the race should be made. It would at least be possible to study the effects of practice runs of different lengths.

REFERENCES.

Cabot: Clinical Examination of the Blood. Fourth Edition.
Schultz: Deut. Arch. f. klin. Med., 1893, p. 234.
Burrows: Amer. Journ. Med. Sci., May, 1899.
Capps: Amer. Journ. Med. Sci., June, 1896.
Larrabee: Journ. Med. Research, January, 1902.

THE HEARTS.

BY RALPH C. LARRABEE, M.D., AND LAWRENCE W. STRONG, M.D.

In 1900 all men presenting themselves before or after the race were examined by the usual methods, as was done by Williams and Arnold in the race of 1899. Owing to the noise and confusion, much difficulty was experienced in making accurate observations. Especially at the start this was the cause of nervousness on the part of the runners, which must be taken into account in interpreting the results. Many men were necessarily examined while standing, and this led to difficulty in getting satisfactory tracings of the percussion outlines. The recumbent posture ought always to be used. After discarding all unsatisfactory records, there remained ten cases upon which our study for 1900 was based.

Size. — Every heart before the race showed symmetrical enlargement to percussion, moderate in degree. At the finish there was invariably a further enlargement, moderate or slight in degree. Four showed general enlargement, two enlargement to the right, one to the left, one to the left and upwards and two upwards. In seven of the ten complete cases and in several examined only at the start there was visible bulging of the precordia. This was present at the start and was not affected by the contest.

Murmurs.— Before the start, out of eighteen men examined, three showed auscultatory abnormalities. One of these (M.) had a prolongation of the first sound, heard midway between the xyphoid and the apex, not transmitted and without accentuation of the pulmonic second. It remained unchanged at the finish. The heart was rapid and slightly irregular. We believe that the murmur was functional. In a second case (P. L.) there was marked enlargement to the right before the race, and there was also a short systolic murmur to the right of the sternum at the nipple level. Five minutes after the finish this murmur was barely audible, while the cardiac area had extended to the left. The third case was an old, experienced runner (McA.) who had recently recovered from influenza. Before the race he was nervous and excited, and had a temperature of 100.7° F. He had the usual symmetrical enlargement of the heart. The murmur was systolic, heard at the second left interspace and transmitted a short distance toward the apex. The heart's action was slightly irregular. After the race he was examined immediately, but no murmur could be heard, and the heart was regular. In but one case (T.) was a murmur detected at the finish which was not present at the start. This was systolic and heard over the pulmonic area. The man had walked the last nine miles and showed no fatigue when examined. These murmurs, like all of those heard in this investigation, were of slight intensity, and were soft and blowing in quality.

A variable, and in some cases a considerable, time elapsed between the finish and the examination of the chests, as the sphygmograph and blood tension tests were made first, but the men still showed general exhaustion and cardiac dilatation. In four cases the examination was immediate; the longest delay was a half hour.

In the race of 1901 the faults of the previous year's observations were corrected, especially as to the delay in auscultation at the finish, which has been held accountable for the absence of new murmurs. Fewer men were examined, with greater individual

care. Two and three days before the race several men were examined at their gymnasiums, and of these four finished, while several others afforded partial observations. The results obtained by inspection and percussion of the heart's area were the same as in 1900; there was always some enlargement before the race with further increase during it. Two (J. L. and H—ks) showed marked enlargement during the race; one (P.) showed moderate increase; but the fourth (McA.) showed little or none. All men were examined in the recumbent position, and great care was taken with the tracings. The results from percussion are certainly as accurate and significant as those obtained by auscultation. Of these four men one (H—ks) had no murmur either before or after the race; one (McA.) had no murmur at the start, but had a systolic murmur at the base on both sides of the sternum at the finish; the third (J. L.) had a soft booming systolic murmur, apical at the start and basal at the finish; the fourth (P.) showed at the start a systolic murmur over the whole precordial area. At the finish the first sound was noted to be impure at the apex, the abnormality being considered cardio-respiratory.

Several other men were examined both before and after the race with reference to heart sounds only. In a few of these systolic murmurs were heard both before and after the race, and in but one case was a murmur found at the finish which was not also heard at the start. This was systolic in time and was heard at the base. Exact figures as to the number examined cannot be given, as the record was lost in the confusion of the finish.

In 1902 four complete records were again made, while nine other men were examined for heart sounds only, both at start and finish. The four complete cases showed hearts that were symmetrically enlarged before the race and that underwent further enlargement during the race. There was no uniformity in the direction of the enlargement, either to right or left, and this observation holds true for all three years. The degree of enlargement during the race was slight.

Auscultation of the four complete cases, examined by the same observers both before and after the race, showed two men (H—ks and C.) without murmurs both at start and finish. The third (P.), noted to have a faint, soft, systolic murmur at the apex two days before the start, was without a murmur at the finish, while the fourth (J. L.), noted to have a slight impurity of the first apical sound at the start, had a systolic murmur at the finish. It would be unfair to regard this murmur as new-formed during the race; it was obviously an accentuation of the impurity heard before.

Of the nine men of whom we have no other record at the start than the statement of the examiner that he heard no murmurs, six showed murmurs at the finish. Of these three were cardio-respiratory, ceasing on holding the breath, and the other three were apical systolic murmurs, apparently developed during the race. There was no delay in auscultating at the finish. The murmurs were very slight in intensity.

In all three races some men were cyanotic at the finish, and others were pale. Bleeding from the mouth or nose did not occur. In 1900 a number of the other men vomited, but only after taking food or water.

The enlargement of the heart before the race, invariably present in our cases, agrees with the work of other observers, and means hypertrophy, the result of training. It is to be compared to the hypertrophy of the peripheral muscles (which, it may be said, was not marked in these runners) and, far from being an abnormality, is probably essential to successful running.

The presence of so many systolic murmurs before the race (six out of eighteen cases) is more difficult to explain, and is wholly at variance with the results of Williams and Arnold, who studied this same race in 1899. They found no such murmurs in any of their cases. The discrepancy may perhaps be accounted for by the different conditions under which the examinations were made. In Williams and Arnold's cases the examinations were made several days before the race, and the examiners thus became acquainted with their men. The number was smaller, as was also the number of contestants, and consequently there was less excitement at the start when the final observations were made. In ten of our eighteen cases the first examination was made at the starting-point. The increasing fame of the event brought a greatly increased number of entries, and this, with the greater public interest, made much more excitement at the start than ever before.

We believe, therefore, that most or all of these murmurs before the race were due to nervous excitement. Similar murmurs have been noted by Morton Prince in candidates for the Boston Fire Department. When he examined men under circumstances calculated to produce nervous excitement, the murmurs were frequent, but when the excitement was reduced to a minimum they were rare. Out of our six cases showing murmurs at the start, the abnormal sounds had disappeared at the finish in four, and in one other the murmur was scarcely audible. Perhaps this was because at the finish the men were too much exhausted to be "rattled." Some of the murmurs may have been due to other causes, — the persistent ones possibly even to old valvular endocarditis, — but probably most of them were caused by nervousness.

We recognize that in attributing the murmurs to nervous excitement we are but stating the results of observations without adequately explaining them. How excitement produces the murmurs we cannot at present say. A discussion of the question would lead us into theories beyond the limits of this paper. We cannot, however, unreservedly accept Prince's view that they are due to mitral regurgitation from relaxation of the mitral sphincter.

After the race there was further increase in the heart area in sixteen of the eighteen cases. We attribute this to temporary acute dilatation. But why should the heart be dilated where the blood pressure is so remarkedly decreased as it was in these cases? There are two possible answers. It is generally admitted that in brief exercise (or in the early part of continued exertion) the blood-pressure is raised. Darling has shown that, even after the comparatively brief exertion of a boat race, dilatation of the heart occurs. Stengel considers that the dilatation found in the presence of low blood-pressure repre-

sents the failure of the heart to recover from dilatation that occurred in the early period of high tension. The other explanation is that the dilatation represents relaxation of the heart's muscular tonus as a result of exhaustion or "fatigue products."

In regard to the murmurs found after the race, as in these found before, our results differ from those of Williams and Arnold, who found systolic murmurs in eleven out of thirteen cases. Of our eighteen cases fully examined, but six had murmurs at the finish, and in four of these the murmur was also present at the start. Of the thirty or forty cases examined by auscultation alone, we found but four more who had a murmur at the finish only.

The cause of the murmurs heard after exercise is a matter of much doubt. We do not consider that our cases bear out the theory that they are always or usually due to regurgitation from the left ventricle consequent upon relaxation of the so-called mitral sphincter. The natural explanation of the discrepancy between our results of 1900 and those of Williams and Arnold was that too long a time had elapsed between the end of the race and the examination. They distinctly state that the murmurs were fugitive, often lasting less than a minute. This objection does not apply to our work in 1901 and 1902. The discrepancy may be partly explained by difference in weather, as well as by the difference in surroundings already referred to. Moreover it seems to us that their fugitive nature is opposed to the explanation as mitral regurgitation, for the strain had continued for hours and the murmurs often disappeared while the general exhaustion and cardiac dilatation persisted.

The lack of signs of engorgement of the lungs and the character of the sphygmograph records are opposed to the supposition of mitral regurgitation. The capricious occurrence of the murmurs in our cases and their somewhat variable locations suggest that no one cause accounts for them all. While we do not deny the possibility of slight mitral leakage we are unable in our cases to find evidences of it beyond the occurrence of murmurs in systole.

We found no clear evidences of dilatation of the pulmonary conus arteriosus, which some writers have offered as an explanation of the systolic murmurs at the base. But the recognition of comparatively slight degrees of this condition is at least difficult, and we would suggest the desirability of studies with the X-ray. Stengel believes that the systolic murmurs at the pulmonic area and apex are due to dilatation of the pulmonary conus arteriosus, and continues: "The murmurs at the apex may undoubtedly be due to mitral regurgitation, but I cannot convince myself that all found in this situation are of this nature. Some, I believe, are intraventricular; others, possibly cardio-pulmonary in origin." With this unsatisfactory statement we must at present be content.

The subsequent condition of the men we were unfortunately unable to follow. We received letters from the four men studied fully in 1901, and, except for a case of badly blistered feet, all were as well as ever in a day or two. So far as we know no one has ever suffered serious or permanent harm from this race. In fact the changes, so far as the heart is concerned, must be regarded as physiological.

REFERENCES.

Darling: Boston Med. and Surg. Journ., Aug. 31 and Sept. 7, 1899; also June 6, 1901.
Prince: Med. Rec. (N. Y.), April 20, 1889.
Prince: Amer. Journ. of the Med. Sci., February, 1901.
Stengel: Amer. Journ. of the Med. Sci., November, 1899.
Williams and Arnold: Phila. Med. Journ., June 3, 1899.
Larrabee: Boston Med. and Surg. Journ., Sept. 18, 1902.

KIDNEYS.

BY JOHN M. CONNOLLY, A.M., M.D.

In the three accompanying tables are given the results of the examinations of the urine for the three years 1900, 1901 and 1902. A few words in explanation of these tables are necessary.

METHODS.

The urine of each contestant from whom it was possible to obtain a specimen was examined. The urine was collected at Ashland just before the start and at the Boston Athletic Association Building as soon as it could be passed after the race. The examination was begun immediately and was completed as rapidly as possible, in order that all determinations might be made while the specimens were still fresh. The *amount* was measured, and the *color*, *odor* and *reaction* noted. The *urea* percentage was estimated by Squibb's ureometer. *Albumin* was tested for by both the nitric acid and the heat test, and *sugar* by Fehling's test, which was allowed to stand for twenty-four hours. All of these tests were made in every instance, and the *specific gravity* was taken in every case in which a sufficient amount of the urine was obtained.

Uric acid, *chlorides* and *phosphates* were quantitated in all those cases, nineteen in number, in which a specimen of the urine both before and after the race was obtained and a sufficient quantity remained after the performance of the other tests. The *uric acid* was quantitated by means of the centrifuge, by the ammoniacal argentic nitrate solution, after precipitating and removing the phosphates. The *chlorides* were estimated by titration with argentic nitrate, and in the year 1901 all the specimens both before and after the race were first titrated with argentic nitrate in the usual way. The organic matter was then removed by the Neubauer-Salkowski modification of Mohr's method, and titration with argentic nitrate again done.

The results here were interesting as showing the correctness of the rule which requires the subtraction of one cubic centimeter from the reading when the amount of argentic nitrate used amounts to 10 cubic centimeters or over. It was found that each cubic centimeter of argentic nitrate required when the organic matters were not removed corresponded almost exactly to $\frac{9}{10}$ of a cubic centimeter required after the organic matters were removed.

The *phosphates* were estimated by titration with uranium acetate, and for the year 1900 by the centrifuge also. For 1901 and 1902 the method by titration was chosen as being the more accurate.

The explanations already given apply to all the urines. In the year 1902 it was found possible, for the first time, to secure the twenty-four-hour amounts both before and after the race. This was done from three runners, and from one of these an additional twenty-four-hour amount was obtained

1900.	No. of Urine.	Amount in c.c.	Color.	Reaction.	Sp. Gr.	[1] Urea, %.	Uric Acid, %.	Chlorides, %.	Phosphates, %.	Albumin.
H. H. P. C.	1	120	Normal	Neut.	1.018	1.64	0.024	0.668	0.12	0
		90 [2]	*High Normal*	*Str. acid*	*1.030*	*2.46*	*0.082*	*0.212*	*0.19*	*Sl. trace*
T. M.	2	125	Normal	Acid	1.028	2.59	0.035	0.704	0.17	0
		120	*High Normal*	*Str. acid*	*1.027*	*2.08*	*0.024*	*0.670*	*0.15*	*Sl. trace*
D. G. (?)	3	110	Normal	Sl. acid	1.025	2.90	0.082	0.795	0.14	0
		240	*Normal*	*Str. acid*	*1.021*	*2.40*	*0.018*	*0.273*	*0.30*	*V. sl. trace*
F. C.	4	128	Normal	Acid	1.028	3.03	0.059	1.214	0.11	0
		90	*High Normal*	*Str. acid*	*1.027*	*2.21*	*0.047*	*0.849*	*0.09*	*Sl. trace*
E. C. R., Jr.	5	130	Normal	Sl. acid	1 027	2.71	0.035	0.789	0.125	0
		120	*Sl. H. Normal*	*Str. acid*	*1.026*	*2.40*	*0.024*	*0.304*	*0.15*	*V. sl. trace*
H. N.	6	120	High	Acid	1.029	2.40	—	—	—	0
		60	*High*	*Str. acid*	*1.034*	*1.89*	—	—	—	*Sl. trace*
T. J. H—ks	7	30	Normal	Acid	—	2.96	—	—	—	0
		90	*High Normal*	*Str. acid*	*1.024*	*2.46*	—	—	—	*Trace*
H. L. W.	8	120	Normal	Acid	1.026	3.20	—	—	—	0
		20	*High Normal*	*Str. acid*	—	*2.40*	—	—	—	*Trace*
J. L.	9	60	High Normal	Acid	1.029	2.59	—	—	—	0
		30	*High Normal*	*Str. acid*	—	*2.14*	—	—	—	*Trace*
J. J. Q.	10	90	High Normal	Str. acid	1.021	2.77	—	—	—	Sl. poss. tr.
		60	*High*	*Str. acid*	*1.026*	*2.27*	—	—	—	*Sl. trace*
W. K. C.	11	90	Normal	V. sl. acid	1.020	1.64	—	—	—	0
		30	*Normal*	*Str. acid*	—	*2.77*	—	—	—	*Sl. trace*
L. B.	12 [3]	30	Normal	Acid	—	2.77	—	—	—	0
		120	*Sl. H. Normal*	*Str. acid*	*1.021*	*2.65*	—	—	—	*V. sl. trace*

[1] In these quantitative estimations Dr. F. T. Lewis, Austin Teaching Fellow, Harvard Medical School, gave valuable aid.
[2] After the race, in *italics*.
[3] Completed 7 miles only.

1901.	No. of Urine.	Amount in cc.	Color.	Reaction.	Sp. Gr.	[4] Urea, %.	Uric Acid, %.	Chlorides, %.	Phosphates, %.	Albumin, %.
D.	13 [5]	140	Pale Normal	Acid	1.025	3.03	.117	1.03	.0900	0
		200 [6]	*Pale N. sl. tur.*	*Str. acid*	*1.020*	*2.27*	*.024*	*0.33*	*.1060*	$\frac{1}{120}$
S.	14 [7]	130	Normal	Acid	1.030	3.28	.035	0.89	.1575	0
		125	*N. sl. turbid*	*Acid*	*1.026*	*2.96*	*.017*	*0.78*	*.0900*	$\frac{1}{300}$
C.	15	60	Normal	Acid	1.020	2.52	.012	0.76	.0225	0
		65	*Normal*	*Str. acid*	*1.015*	*1.45*	*.023*	*0.44*	*.0338*	$\frac{1}{60}$
K.	16	140	Normal	Acid	1.025	3.28	.053	0 80	.0600	0
		135	*Normal*	*Acid*	*1.030*	*2.65*	*.141*	*0.38*	*.2250*	$\frac{2}{40}$
G.	17	40	Pale	Acid	1.026	3 03	—	0.96	.0675	0
		65	*Normal*	*Str. acid*	*1.030*	*2.90*	—	*0.46*	*.1013*	$\frac{1}{60}$
P.	18	75	Normal	Faintly acid	1.025	2.72	.012	0.90	.0675	0
		130	*Normal turbid*	*Acid*	*1.020*	*2.08*	*.023*	*0.42*	*.0890*	$\frac{1}{90}$
DeV.	19	75	Pale	Str. acid	1.027	3.10	.128	0.80	.1013	0
		200	*Pale*	*Acid*	*1.022*	*2.58*	*.012*	*0.34*	*.1125*	$\frac{1}{60}$
H—ks	20	80	Normal	Acid	1.028	2.90	.081	0.84	.1350	$\frac{1}{120}$
		75	*Normal*	*Str. acid*	*1.022*	*2.65*	*.012*	*0.37*	*.0450*	$\frac{1}{20}$
P.	21	90	Pale	Sl. alk.	1.025	1.96	.025	0.89	.0225	0
		160	*High Normal*	*Str. acid*	*1.022*	*2.02*	*.012*	*0.27*	*.0450*	$\frac{2}{40}$
F.	22	60	Pale	Faintly acid	1,018	1.51	.059	0.78	.0225	0
		135	*High*	*Str. acid*	*1.027*	*2.40*	*.108*	*0.38*	*.1800*	$\frac{11}{240}$
E.	23 [8]	70	Pale	Faintly acid	1.020	2.21	.015	0.74	.0338	$\frac{1}{60}$
		140	*Pale*	*Faintly acid*	*1.013*	*1.70*	*.006*	*0.50*	*.0338*	$\frac{1}{48}$
J. L.	24	140	Normal	Acid	1 030	3.22	.011	0.68	.1013	0
		160	*N. sl. turbid*	*Str. acid*	*1.016*	*2.14*	*.029*	*0.17*	*.0788*	$\frac{7}{80}$
McA.	25	35	Pale	Str. acid	1.027	2.40	—	1.19	.0563	0
		110	*Normal*	*Str. acid*	*1.016*	*2.27*	—	*0.51*	*.1350*	*0*
McD.	26	50	Sl. pale	Acid	1.026	3.31	—	1.05	.0900	0
		300	*Normal*	*Str. acid*	*1.206*	*2.98*	—	*0 44*	*.2250*	$\frac{1}{60}$
M.	27	130	Normal	Acid	1.025	3.15	—	1.01	.0900	$\frac{1}{120}$
		125	*Normal*	*Str. acid*	*1 024*	*3.03*	—	*0.54*	*.1140*	$\frac{1}{48}$

[4] In these quantitative estimations Mr. W. E. Connolly, Harvard Medical School, gave valuable aid.
[5] Ran only 18 miles.
[6] After the race, in *italics*.
[7] Ran only 15 miles.
[8] Ran only 20 miles.

1902.	No. of Urine.	Amount in cc.	Color.	Reaction.	Sp. Gr.	Urea, %.	Grams of Urea in 24 hours.	Uric Acid, %.	Chlorides, %.	Grams Chlorides in 24 hours.	Phosphates, %.	Albumin.
C.	28	1,200	Normal	Acid	1 027	2.65	31.80	.117	.759	9.11	.0956	0
		1,130 [9]	*High*	*Acid*	*1.030*	*2.02*	*22.82*	*.017*	*.243*	*2.75*	*.1013*	$\frac{1}{120}$
H—ks	29	1,250	Pale	Acid	1.030	3.15	39.375	.081	.807	10.09	.0790	0
		1,180	*High*	*Acid*	*1.030*	*3.28*	*38.704*	*.141*	*.564*	*6.66*	*.1131*	$\frac{1}{300}$
O'B.	30	1,225	Normal	Acid	1.021	2.07	25.602	.025	.893	10.94	.1060	0
		1,120	*High*	*Acid*	*1.023*	*2.27*	*25 424*	*.011*	*.443*	*4.96*	*.1013*	$\frac{1}{120}$
	10	1,500	High	Acid	1.030	2.77	41.55	.029	1.052	15.78	.1125	0

[9] After the race, in *italics*.
[10] "30" one week after the race.

one week later. As the results for 1902 were in harmony with those for the two preceding years, the table for 1902 contains only the results of examinations made of these twenty-four-hour amounts.

RESULTS.

The most important facts learned by these examinations are summarized in the tables.

Quantity. — In most cases the quantity of urine passed after the race was quite small. The average time at which the small amounts given in the tables were passed was one and a half hours after the finish. Some of the contestants were able to pass urine almost immediately after the race. In most of these cases the quantity was rather large.

Color. — The color was in every instance higher after the race than it had been before the race. In several cases the difference was very marked. Many of the urines passed after the race were slightly turbid and a few slightly, but distinctly, smoky.

Reaction. — After the race the acidity, as shown by the intensity of the color given to litmus paper, was in every case markedly increased.

Specific gravity. — In many cases the quantity of urine secured after the race was so small that the specific gravity could not be obtained by the urinometers at hand. In the cases in which estimation could be made, there was no constant relative increase or diminution. The majority, however, showed relative diminution after the race.

Urea. — For 1900 and 1901 the percentages only could be obtained. In the majority the percentage of urea after the race was relatively diminished. Much more satisfactory are the results of the 1902 examinations, because in three cases the twenty-four-hour amounts were obtained. In two of these cases the urea was practically the same before and after the race, in one considerably diminished. It is worthy of note that in the one case in which the twenty-four-amount was obtained one week after the race the quantity of urea had risen markedly. It would be interesting to know if this rise is constant.

These results agree very well with the results from the researches of Fink and Wislicenus in their ascent of the Faulhorn, and also with the later work of Voit and of Parkes, who says that "there is no distinct increase in the excretion of urea after muscular exercise." There probably is no immediate increase after excessive exercise. I am inclined to think, however, that with the Marathon runners there is a later increase depending, as regards the time of its occurrence, upon the time when the men regain their normal appetite. In this connection it is interesting to see that in two cases in 1900, in which it was possible to follow up the urine, the urea percentage still remained below normal three days after the race, and both men declared that they had not yet (April 22, 1900) reached their normal appetite.

The results harmonize also with those of Dr. E. A. Darling in his study on the Harvard University Crews.[11] He well points out the agreement of these results with previously noted facts as follows: "Physiologists have proved that an increase in the urea elimination above normal limits is usually caused by an increase in proteid digestion and not by an increase of muscular action."

Of course, these examinations and any conclusions based upon them are very unsatisfactory. If we could have the urines for two weeks before the event and for two weeks after, and could secure the whole twenty-four-hour amounts, results of absolute value might issue, but it is feared that this state of things will not soon obtain. Many of these men come from distant places to take part in the race, and usually leave for their homes as soon as possible after the race. And even those who live in the vicinity of Boston are not particularly impressed with the importance of these researches, and "with the best intentions" they, like college students,[12] sometimes forget, and some of the urine is lost. Only those who have had actual experience in the work know the difficulties in the way of a full and satisfactory examination of a runner, tired after a Marathon race.

It is unfortunate that of the three twenty-four-hour amounts, two had urea percentages relatively increased after the race. This is contrary to what was found in the majority of cases examined both in this and in the two preceding years.

If in the majority of cases the urea percentage is relatively diminished after the race, and the quantity for twenty-four hours is also diminished, as would seem to be the case, the results for total urea in the table for 1902 are probably exceptional. Of course, neither from three cases nor from thirty can inferences of any great value be drawn. The work, however, constitutes a beginning which may be elaborated.

Uric acid. — I expected the uric acid to be increased after the race. It would seem, instead, in the majority of cases, to be diminished.

Chlorides. — The chlorides were consistently diminished after the race. The results given in the table for 1901 are the most accurate, as especial pains with the chlorides were taken in this year, as already stated. It will be noted that after the race there is an average diminution of about 50% in the chloride percentages. The table for 1902 with its total twenty-four-hour quantities corroborates fully the results previously obtained.

Phosphates. — The phosphates apparently vary without law.

Albumin. — Albumin was absent from all but four of the urines before the race. Albumin was present after the race in every urine. The amounts varied as the tables indicate. It is of interest to note here that Dr. Darling found in the twenty-four-hour amounts several days after the boat races albumin "in 48 out of 83 specimens." "The amount," he says, "was never more than a trace." And it is his opinion that "the traces found in the twenty-four-hour specimens," after a race, "really represented a considerable amount of albumin passed in one urination after rowing, diluted with non-albuminous urine passed during the rest of the day."[13]

With a view to ascertaining whether this opinion is correct, the urines for 1902, in which the twenty-four-hour amounts were preserved, were saved with each urination in a separate vial. It was found

[11] Boston Med. and Surg. Journ., vol. cxli, no. 10, p. 231.

[12] Darling: loc. cit.

[13] Darling: loc. cit.

that in two cases the amount of albumin was greatest in the first quantity passed and rapidly diminished; but in one of the three cases the percentage in the second urination was a little more than in the first, and this in spite of the fact that the quantity of urine passed at this second urination was slightly greater than that obtained at the first. All the urinations for the twenty-four hours contained some albumin. It is probable, then, that it would be nearer the truth to say that the quantity passed at the first urination generally contains most albumin and that this is diluted with *less* albuminous urine passed during the rest of the day. I am satisfied that in the Marathon racers the albumin persists, in the majority of cases, for at least thirty-six hours after the race; but from two urines which I obtained in 1900 three days after the race, and from one urine passed one week after the 1902 race, albumin was entirely absent. The quick recovery is remarkable when attention is paid to the sediment found in these cases immediately after the race. The fact that in three years only four contestants had albumin just before the race after the training that most had undergone is also noteworthy in contrast with "the albuminuria in the urine of a large proportion of the squad under ordinary conditions of training" for the crews.[14] Does running involve less strain on the kidneys than rowing?

Sugar. — Sugar was absent in all cases before the race. After the race a slight reduction of Fehling's solution was noticed in two urines of the year 1900. In both of these there had been no reduction on boiling, and the reduction was not visible at the end of eight hours, but was seen at the end of twenty-four hours. It was very slight and was probably not due to sugar.

Sediment.—Like the chlorides, the sediments were consistently alike.

In most of the urines before the race only a few squamous cells were found in the sediment. In a few of the sediments a rare calcic oxalate crystal was found, and in three a rare acid sodic urate crystal.

In the cases before the race which contained albumin, however, the sediments were alike in showing an exceedingly rare pure hyaline cast, a few leucocytes, a few small round cells and an exceedingly rare abnormal blood globule.

After the race every sediment contained large numbers of hyaline and fine granular casts, a few coarse granular and epithelial casts. There was in all cases more or less blood, normal and abnormal, free and on casts. The amount of blood usually varied directly as the amount of albumin. Brown granular casts were found rarely in many of the sediments, and calcic oxalate crystals, both primary and secondary, in the majority. Spermatozoa were found in several cases. Leucocytes were not many, and there were only a few renal cells free, though many were seen adherent to the casts. The sediments from the urines of several runners who completed distances of from only seven miles up to fourteen and eighteen differed in no respect from those of the contestants who finished. The urines of two of the bicycle riders detailed to accompany the runners also had sediments exactly like those of the runners themselves. In the specimens obtained three days and one week after the race only a few squamous cells were found.

It would be a valuable supplement to these observations if the sediments from the urines of race horses could be examined after a Charter Oak meet or some similar event.

[14] Darling: loc. cit.

PHYSICAL CHARACTERISTICS.

It is interesting to consider briefly the general physical characteristics of the men who were successful in these contests. While it is difficult to detect any obvious practical value of Marathon races, in a general way they may be said to resemble the conditions which would obtain in war time during forced marches of small bodies of lightly armed troops. The analogy is closer than would at first appear, because the race represents not a single effort, but the final test of a long series of practice runs, and because many of the same contestants compete year after year. The length of the course and the speed maintained (in 1901 the winner's time for the entire distance was 2 hours and 29 minutes) would counterbalance the absence of uniform and accouterments. The first three or four men in each race showed, as a rule, the same general physical characteristics, as follows:

Height, medium or less than medium; weight, 110 to 140, and more frequently approaching the former than the latter extreme; chests, not unusually large, nor was the chest expansion very great; legs, of medium length; muscles, never remarkably hypertrophied, but always firm and free from fat; feet, usually large and broad, without evidences of compression in tight shoes; hearts, invariably enlarged, and proportionately more so than the slower runners. In street clothes these men recalled the privates of the French and Austrian rather than the English or German armies, and the traditional "long, lanky Yankee greyhound" was certainly conspicuous by his absence.

It has been asserted by military critics that in time of war mobility of forces is of the first importance. The Marathon races of the past five years prove that it is entirely possible to train considerable numbers of picked young men to develop speed far beyond anything hitherto obtained in modern armies, except in the very rarest instances. Whether this proven fact is of any practical value remains to be seen.

If we consider the speed at which the winners ran, the character of the roads, the frequency of hills and the oppressive atmospheric conditions, it seems marvelous that the human body can be trained to withstand so much with so comparatively little depression. The unpleasant results of longest duration seem to have been blisters on the soles of the feet. In the entire three years we neither saw nor heard of any serious, persistent after-effects, and it is yet to be proven that even these strenuous contests leave behind them any permanent injury.

A large number of men beside those whose names are affixed to the various sections have assisted in making these observations: In 1900, Drs. J. L. Frothingham, McCurdy, Meylan, Fulton, P. Thorndike and Professor J. Hough; in 1901, Drs. W. E. Faulkner, Franz, H. L. R. Crandon and W. H. McBain; in 1902, Drs. Frothingham, R. Hammond and Peters.

SAMUEL USHER, BOSTON, MASS